ARTISANAL SKILLS, WATCHMAKING, AND THE INDUSTRIAL REVOLUTION: PRESCOT AND BEYOND[1]

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ABSTRACT: The role of skills and human capital during England's Industrial Revolution is the subject of an old but still ongoing debate. This paper contributes to the debate by assessing the artisanal skills of watchmakers and watch tool makers in southwest Lancashire in the eighteenth century and their links to apprenticeship. The flexibility of the training regime and its evolution are discussed, as is the decline of the industry.

Keywords: apprenticeship, Industrial Revolution

JEL codes: N00, N33

Artisanal Skills in Watchmaking

The role of skills—whether artisanal, arithmetical, scientific, or being able to read and write and count—in British industrialization is an enduring source of debate. Against an older tradition that interpreted the technologies of the Industrial Revolution as reducing skilled craft workers to an undifferentiated proletarian mass, historians of technology such as Albert Musson and Eric Robinson have stressed the continuing demand for artisanal skills.[2] Margaret Jacob[3] has argued for the role of science and mathematics, while Gillian Cookson[4] has highlighted the contribution of "ingenious" proto-engineers of humble origins in the textile engineering sector. The nature of the requisite human capital continues to be debated, as do the relative status of skilled and better educated workers and the role of the English system of apprenticeship as a help or a hindrance in supplying the necessary training.[5]

In a recent study Morgan Kelly and Cormac Ó Gráda[6] linked the achievement of one small but important eighteenth-century English industry, watchmaking, to a skilled labour force raising productivity through increasing specialisation and learning-by-doing. This paper focuses on those artisan watchmakers in more detail, reviewing how they acquired their skills, the role of literacy, the link between skills in watchmaking and in other sectors, and the eventual demise of artisanal skills in watchmaking. Apart from its considerable intrinsic interest, the history of watchmaking in England is important for the light it can shed on the link between what was in the beginning essentially a cottage industry based on an artisanal workforce and the human capital required for the Industrial Revolution.

I

Most watchmakers in England in the eighteenth century were to be found in three areas: southwestern Lancashire, Coventry, and London (Figure 1). The industry came to be linked particularly to Prescot, a village located about eight miles due east of Liverpool, and its hinterland. A key issue is how a

network of watch- and watch tool-making artisans, who would acquire a global reputation for their skills, developed there. The trade in watch movements between southwestern Lancashire and London, where they were finished and sold, was helped by a good coach service between Warrington and the capital. In the early eighteenth century "ye Bell in Wood Street", the terminus of the Warrington-London coach, was a frequent destination of Prescot watch movements intended for a well-known finisher.[7] The watch movements made in Lancashire were world-class; those made around Coventry, were "considered not so good".[8]

Figure 1 about here

The history of watch- and watch tool making in southwest Lancashire, i.e. the area roughly encompassing the Liverpool-Wigan-Warrington triangle, from its beginnings in the seventeenth century to its demise in the nineteenth, has long been linked to ample coal supplies and long-standing associations with metal-working.[9] The precise origins of the trade are nebulous, however. The region's first watch movement maker has been described as a certain "Woolrich", reputedly a late sixteenth-century Huguenot refugee[10]; but the earliest surviving specimen from the area was made by one Thomas Aspinwall of Toxteth Park, who died in 1624.[11] Several other pre-1700 watchmakers in the area have been identified but entries in Liverpool Museum's database of watch- and clockmakers are relatively few before that date and the first entries for Prescot, and which would later become synonymous with watch- and watch tool making, date from the 1710s. The earliest "authentic" mentions that Hoult[12] could find for Prescot refer to 1673 and 1680; Hoult also notes that in the early eighteenth century the trade in Prescot was limited to tool- and component- rather than to movement makers, which would be consistent with Liverpool watchmakers putting out work to their rural hinterland.[13] Thereafter Prescot entries accumulate, although always outnumbered by Liverpool's in the Liverpool Museums database. By the late eighteenth century, however, the

excellence of Prescot's watch-tools went "beyond the memory of the oldest watch-makers" and the district's "watches, watch tools, files, and pinion wire… [were] universally allowed to be the best in the world"; and "all the other centres of watchmaking in England… have been dependent on the Prescot makers for the foundation of the Watch, technically called the movement". Prescot and its hinterland became a byword for "manufactures of certain groups of hardware, particularly the best and almost all the watch-movements used in England, and the best files in Europe".[14]

Prescot was the epicentre of a district embracing the parishes of St. Helens, Rainhill, Cronton, and Widnes which became synonymous with the production of watch components, watch movements, and watch tools. Manufacture there was "greatly subdivided". As noted, Lancashire watch movements tended to be finished in London, implying close ties between the artisans of the northwest and traders in the metropolis. The networks linking component makers, tool manufacturers, the suppliers of raw materials, and finishers must have been varied and extensive.[15]

A key feature of the industry around Prescot during its golden age in the eighteenth century was its proto-industrial character: early in the century in the notebook of watchmaker Richard Wright entries of husbandry mingle with those on watchmaking, and Aikin described the watchmakers in the 1790s as "occupying small farms in conjunction with their manufacturing business" much like the weavers around Manchester.[16] Still, watchmakers and associated artisans were also to be found in more urban settings and, indeed, they were numerous in parts of Liverpool. While the industry may have originated in Liverpool, the attraction of the coal-rich villages to its east with their plentiful supplies of artisans skilled in working with metals, would have been clear. Another feature was the length to which the industry pursued the division of labour, with several sources providing lists of the dozens of sub-tasks involved.[17] A third was how watchmaking spawned the production of high-quality metal tools for watch and clock making.

The significant productivity growth in English watchmaking during the eighteenth century identified by Kelly and Ó Gráda[18] was built on these

foundations. While conceding the role of key innovations such as the lever escapement mechanism (due to Thomas Mudge, 1765), John Wyke's wheel-cutting engine (c. 1760), and crucible steel (invented by Benjamin Huntsman in the 1740s), they highlight the role of incremental and continuous artisan-driven productivity change. They reckon that productivity grew at an annual rate averaging nearly one per cent during the eighteenth century.

II

Watchmaking, in common with most trades in early modern England, was subject to the Statute of Apprentices of 1563, which made practicing a trade without formal training as an apprentice illegal. In 1642 the Recorder of London stipulated that in order to practice their trade watch- and clockmakers had to be members of the London-based Clockmakers' Company.[19] An apprenticeship lasting seven years was a precondition for admission. At the outset the Clockmakers Company kept a tight rein on the industry in the metropolis, limiting entry and strictly controlling the quality of output, but its power did not last. Although in principle its remit was countrywide, it is unlikely that in practice its right to search for items of "insufficient" quality extended much beyond the metropolis. By the 1730s the Company had abandoned its searches even in London as an interference with "the liberty of the trade".[20]

By the time [1776] Adam Smith excoriated the guild system for being "altogether unnecessary" because it restricted competition and because the acquisition of artisanal skills required no "long course of instruction", guilds in England were far from being the institutional encumbrance he deemed them to be. In Smith's day, the time served by apprentices was as much a product of the fluidity of a system in which attrition rates were very high as of the human capital imparted.[21] But not only did a significant proportion of apprentices never serve out their time; many artisans in the allegedly restricted trades were never formally apprenticed. Examples include watch-making in southwest Lancashire (on whom more below), and the woollen industry of the West Riding where "only those who intended to become masters' served their time

formally" and "the rank and file of the workpeople never became formally indentured"[22].

While most apprenticeship contracts stipulated a term of seven years throughout the century, the fee payable was subject to considerable variation.[23] Those apprenticed as part-makers or file-cutters tended to pay somewhat less than those apprenticed as watchmakers, and the cost in both categories tended to fall over time, particularly so for those in bottom decile or quartile of the distributions (Table 1). Apprentices acquired their skills locally: of the hundreds of southwest Lancashire apprentices described below only a handful were trained outside their own immediate area.

Table 1 here

The supply of trained watch-, tool-, and part-makers seems to have responded to market pressures and increasing specialization in the industry, with training increasingly confined to some specialization. This led to a narrowing of skill sets over time: even eighteenth-century indentures from the Prescot area stipulate specializations such as motion maker, pinion maker, balance maker, spring maker, tool maker, gold hand maker, and so on.[24] Of 264 Lancashire pre-1750 apprentices recorded in Dennis Moore's invaluable *British Clockmakers and Watchmakers Apprentice Records 1710–1810* (2003), 48.9 per cent were listed as "watchmakers". In 1750-1779 the proportion was 37.1 per cent of 676 registered; in 1780-1809 it was 20.5 per cent of 322. The Lancashire apprentices listed by Moore include trainee engravers, file cutters, movement makers, pinion makers, spring makers, balance makers, case makers, finishers, gilders, gravers, hand makers, pillar makers, verge makers, wheel cutters, and wire drawers.[25]

A surprising feature of Moore's database is that apprentices from Lancashire (and Warwickshire) represented a far smaller proportion of the total than might be predicted by their dominant role in British watchmaking. Before 1780 Lancashire watch-, tool-, and component makers accounted for 16.2 per

cent of the total; in 1780-1809, for only 8.2 per cent. London's shares were 46.3 and 50.5 per cent, respectively.

Does this mean that the system was fluid and flexible enough to accommodate workers who bypassed formal apprenticeship, and relied instead on training within an extended family network? There is some evidence to support this. According to Dane (1973: 105) in Lancashire the sons of journeyman file-makers tended to learn their trade at home, subservient to their fathers but learning the basic skills quickly. A comparison involving an official listing of eighteenth-century apprentices and parish register data offers further insight into this important question. In 1710 Statute 8 Anne c5 introduced a stamp duty on premiums payable to masters. Moore (1983) lists all watch- and clock-making apprentices who paid this duty between 1710 and 1810. The duty—6d in the £1—was not onerous, and is therefore not likely to have led to appreciable evasion. A potential limitation of this source as a guide to the prevalence of apprentices is that only those who paid a fee were liable to stamp duty. We suspect, however, that the Clockmakers considered their trade too exclusive for non-fee paying apprentices to have been common in the eighteenth century—though pauper apprentices in watchmaking were not unusual in the nineteenth.[26]

A comparison of grooms listed as watchmakers, file cutters, and watch part makers in the Anglican parish records of Prescot and adjoining parishes[27], and in those Liverpool parishes providing the requisite data on occupations and literacy, with fee-paying apprentices from the same parishes recorded in Moore's work implies that only a minority of men employed in the watchmaking trade between the 1750s and the 1800s were formally apprenticed. The number of observations in Table 2 is rather small so inferences are a bit risky. Still, the exercise suggests that many watchmakers did not go through a fully formal training. It also implies, rather strikingly, that those who did so were more likely to be literate than those who did not.

Table 2 about here

At the same time many of those absent in Moore's *British Clockmakers and Watchmakers* had the same surnames as local watchmakers who underwent formal apprenticeship. Some of the latter were presumably family or kinfolk who could have provided informal training. While avoiding formal training saved time and money, the trade-off was a lack of mobility and reduced influence with potential trading partners; and so presumably the more ambitious and entrepreneurial and wealthier opted for formal training. Table 3 addresses this issue; again, literate grooms were more likely to have namesakes included in Moore's database.

Linking apprenticeship and parish register data suggests two important points. First, the apprenticeship system in watchmaking was rather "weak", in the sense that many workers who did not formally serve their time were not barred from the industry. Households and local networks, enhanced through marriage, were a key locus for the transmission of skills. Watchmaking was not immune to the influence of guilds, however; on the contrary, the two interacted in interesting ways. Urban watchmakers were more likely to undergo formal apprenticeship but a minority of their rural counterparts, although organized along protoindustrial lines, also availed of it when beneficial. Second, the transmission of human capital through apprenticeship and through family or clan networks were complementary: the example of watchmaking in Lancashire shows there was room for both institutions, with poorer and less literate workers tending to opt for the former.[28]

Table 3 about here

That watchmakers were highly skilled workers[29] and that the quality of their work was high is not in doubt. Price depended on quality and "social status and respect of the man" reflected the price his work obtained.[30] Those skills owed nothing to formal science, however: "In Lancashire, they make the teeth of watch wheels of what is called the bay leaf pattern; they are formed altogether by the eye of the workman; and they would stare at you for a simpleton to hear you talk about the epicycloidal curve"[31]. Similarly, the cutlers

and tool makers around Sheffield who discovered how to produce crucible steel for their own use in the wake of Huntsman's discovery in the 1740s did so through trial and error, not through book learning.[32]

Nor, for the most part, did the watchmakers' artisanal skills require literacy. Yet when the talented file maker Peter Stubbs married on 6 July 1777 at the age of 21 he signed the register[33], and this was typical in the trade at the time. Although literacy levels in the industrializing regions of south Lancashire were low—even in the 1840s and 1850s one groom in two and nearly three brides in four in our database were unable to sign—most watchmakers were able to sign, at least from the 1750s on when parish registers first supply the details.

The marriage records of several parishes in the Prescot area provide data on male occupations and on the ability of males and females to sign the marriage register from the 1750s on. Table 4 employs those data in order to place watchmaking and a range of other occupations in comparative focus (see also Appendix Tables 1a-1c). An outstanding feature is the relatively high literacy level of watch- and toolmakers. The most plausible reason for this is that the business side of their work—dealing in raw materials, spare parts, and finished clockwork—required literacy. T. H. Ashton[34] noted that many of the workmen who supplied Stubbs of Warrington also traded with others. Indeed, the earliest business record of a Prescot watchmaker, dating from the early 1710s, describes a skilled craftsman supplying the London trade with both movements and files. The record also makes plain that his output relied on the work of others.[35]

The failure of literacy to rise in England during the Industrial Revolution has given rise to the conviction that literacy was not a crucial feature of industrialization. But a closer look at literacy rates by occupation, as proxied by ability to sign the marriage register[36], suggests that this is an oversimplification (Figure 2). Table 4, based on the Anglican marriage records in the parish registers of Widnes, Rainford, and Prescot in southwest Lancashire, indicates the importance in that area at least of literacy in occupations linked to self-employment and to trading (e.g. shoemakers,

wheelwrights, cabinetmakers). Farmers, more likely to be small farmers in this area, also were likely to be literate—and Joan Thirsk[37] has highlighted the role of print in hastening the diffusion of agricultural techniques—and much more so than their wives.

At age twelve Warrington-born Peter Stubs (alternatively Stubbs) was apprenticed for seven years to one Peter Atherton of Prescot. The fee for training as a file cutter was £20. When Peter and Mary Stubs married in 1777, she was unable to sign, and so were the majority of watchmakers' wives at any point between the 1750s and the 1850s. Why the big gender gap in this admittedly crude measure of literacy? Most likely, this reflects the dual character of literacy as consumption and investment.[38] In a relatively poor region such as eighteenth century Lancashire, higher male literacy reflected the investment aspect, since the returns on male literacy were much higher than those on female literacy. Female literacy, on the other hand, is more easily interpreted as consumption at that point, and so is more likely to be observed in high-income marriages such as those of the elite and white-collar workers.[39]

Some of the results in Table 4—the lower literacy of brides, the very low literacy of colliers—come as no surprise. The wives of traders—i.e. grocers, innkeepers, dealers, and the like—are the exception that proves the rule: their literacy had considerable commercial value, whereas that of artisans' wives had not. The gender gap in literacy in watchmaking households reflected an artisan culture in which the uses of literacy were limited.

Table 4 and Figure 2 about here

Rather strikingly, watchmakers and associated toolmakers were more likely to be literate during the heyday of the industry in the second half of the eighteenth century than thereafter. This is most likely linked to the rising proportion of the workforce consisting of journeymen in highly specialist tasks and with no prospects of becoming independent traders.

In most occupation groups the share of females who could sign the marriage register rose between the mid-eighteenth and mid-nineteenth centuries, but not so in the case of watchmakers. This is arguably a reflection on the pressure on watchmakers' incomes towards the end of the period, on which more below. Note, however, that the decline is also in part a reflection of the growing share of toolmakers, who were less likely to be able to sign, in the total (Table 5).

Table 5 here

III

How transferable were skills developed in watchmaking to other sectors? Highly transferable, according to the clockmakers' guild in 1814: "The national advantage derived from the perfection to which the Art of Clock and Watchmaking has been carried in this Country are not limited to the value of its produce, but extend to every branch of manufacture in which machinery is used"[40]. Musson and Robinson[41] broadly corroborate, stressing the importance of the tool-making and metal-working skills of watch- and clockmakers. For example, Henry Hindley (1700-1770), a York-based clock- and watchmaker who had learned his trade in Lancashire, and who was an early mentor of John Smeaton, made machine tools; William West, brother-in-law of Richard Trevithick and clockmaker, apparently made a model of a moving engine for Trevithick[42]; and Brunel served his time with a French clockmaker. Still, the claim must not be stressed too far. Whereas Ben Russell highlights the role of clockmakers, Gillian Cookson[43] cautions that although they were much in demand in the early phases of the Industrial Revolution, their role during what she has dubbed "the age of machinery" was less important.[44] She notes that "the essential innovations in machine-making tools, notably to the lathe and the planer, were the work of engineers such as Wilkinson, Bramah, Maudslay, Clements, Roberts, Whitworth, Fox, Nasmyth and Murray, none of whom was connected with clockmaking".[45] Cookson's caution highlights the difference between the early decades of the Industrial Revolution, when the advances of

industrial technology relied on informal artisan skills, and a later phase when precision and the standardization of parts were central. When Peter Stubs (1756-1806) successfully made the transition from files for watchmakers to much heavier 'Sheffield' files for machinery in the late 1810s, it was still without the help of precise cutting tools: "whether file A was better than file B [was] largely a matter of opinion". But that was about to change.[46]

In the case of watch- and watch-tool makers a few swallows such a John Wyke (1720-1787) or a Peter Stubs hardly made a summer. Still, their role should not be ignored. Wyke, a file cutter and watchmaker born in Sutton near Prescot in 1720, was already a significant player locally when he moved to Liverpool in 1758, finding—so it was claimed—the trade in Prescot overregulated.[47] The first version of his tool catalogue dates from this time and within a decade he was noted for his "instruments in the watch way" and for "all motion work, chains, mainsprings, and pinion wire… of every size, to as many as fifty drawings"[48]. Wyke had close links to some leading industrialists of his day. He produced some cast steel tools for James Watt as early as c. 1760 and ones 'of exquisite construction and fineness; as punches, spatula-like instruments, and gravers' for Wedgwood in 1767-68, some of which were apparently made by himself.[49]

When Wyke's workmen had their hands full, an associate, clock-maker Joseph Finney of Liverpool, was called on. Finney, although primarily a quality clockmaker, was also a watch- and instrument-maker. "A mechanical genius… capable of manufacturing any form of complex mechanical machinery", in the 1760s Finney produced a form of pyrometer which could measure the expansion of heated metal with precision.[50] John Whitehurst of Derby, another clock and instrument maker and friend of Matthew Boulton, was his brother-in-law. Finney was the link between Boulton and Wedgewood when the latter pair first met in 1767.[51] Some years later Boulton developed his famous engine-turning lathe "in close consultation" with Wyke.[52] In 1777 Boulton also got the idea for an engine counter from a pedometer made by Wyke's firm; it supplied the necessary wheels and pinions and also made the frame for what they dubbed the "pocket walking machines".[53]

Prescot-born Peter Stubs began a tool-making business in Warrington in the 1770s, at first operating mainly on the putting-out system; later he built a workshop there in order to increase his control over the quality and quantity of output. His specialty was high quality files, crucial for sharpening tools and flattening surfaces.[54] According to Aikin[55] Lancashire tool makers traditionally stuck to "small files, the best in the world, at a superior price, indeed, but well worth the money, for the goodness of the steel, and the exactness of cutting. They do not attempt making the larger files". The leap from small to large was far from elementary and the switch from watch-tools to engineering tools must have involved considerable investment in plant and re-training, but by 1815 Peter Stubs' son was designing and making bigger files for use in machinery production.[56] Soon his machinery files of up to 20 inches would be described as "Lancashire files".[57]

The quality and variety of made-in-Lancashire machine tools came to be widely acknowledged. Machine tool maker James Nasmyth's account of the abundance of skilled labour "gifted with mechanical instinct" in south Lancashire and Cheshire, is worth quoting at some length:[58]

> From an early period the finest sort of mechanical work has been turned out in that part of England. Much of the talent is inherited. It descends from father to son, and develops itself from generation to generation…
>
> The "P. S.", or Peter Stubbs's files, were so vastly superior to other files, both in the superiority of the steel and in the perfection of the cutting, which long retained its efficiency, that every workman gloried in the possession and use of such durable tools. Being naturally interested in everything connected with tools and mechanics, I was exceedingly anxious to visit the factory where these admirable files were made. I obtained an introduction to William Stubbs, then head of the firm, and was received by him with much cordiality when I asked him if I might be favoured with a sight of his factory, he replied that he had no factory, as such; and that all he had to do in supplying his large warehouse was to serve out the requisite quantities of pure cast steel as rods and bars to the

workmen; and that they, on their part, forged the metal into files of every description at their own cottage workshops, principally situated in the neighbouring counties of Cheshire and Lancashire.

The achievements of Wyke and Stubs suggest that it was in precision tool-making and in working with high-quality metals rather than in watchmaking *per se* that any broader contribution to "the age of machinery" might have been made.[59]

IV

Watchmaking was one of the first English industries to 'fail' after the Industrial Revolution. Its growth preceded and contributed to the Industrial Revolution, but the beginnings of its decline coincided with it. A further irony is that while it is common nowadays to link the origins of the Industrial Revolution to high wages, the decline of watchmaking in England was in large part the product of relatively expensive English labour. Moreover, the virtual exclusion of female labour from watchmaking in Lancashire until near the end may be seen as an attempt to protect male wages, but it placed the industry at a disadvantage relative to Switzerland, where there were no such obstructions.[60]

Having virtually exhausted the scope for productivity growth through specialization in the eighteenth century, English watchmaking found it hard to adapt and innovate in the nineteenth. In the epicentres of the industry, the lure of alternative employments grew and increasing pressure on living standards was the fate of those who clung on. After the restoration of peace in 1815 competition from Swiss watchmakers intensified. The entry on watchmaking in Rees's *Cyplopedia* [1819] ominously concluded with an account of watchmaking in the epicenter of the Swiss industry, the mountainy area around Neufchatel, where women were employed and "the subdivision of labour is carried still further than in ours". Between 1821 and 1831 the number of families in Prescot employed in handicrafts, mainly watchmaking, fell from 869 to 540. "That which this country has lost, Switzerland has chiefly gained"[61].

Swiss watches, it was true, were not perfect substitutes for English watches. At the outset the *forte* of the Swiss was lower quality watches produced by cheap labour. As an indicator of the Anglo-Swiss watch gap, at the beginning of the nineteenth century wages in London were more than double those in Zurich; in 1910 they were still 50-70 per cent higher.[62] Compared to Lancashire and London, the workmanship in Swiss watches was "exceedingly slight". But the latter were sleeker and lighter because they did not rely on the bulky *fusée* (a pulley device that helped to equalize the pull of the spring) that still dominated in England, and although the Swiss reliance on going barrels, invented by French watchmaker Jean-Antoine Lépine, may have reduced their accuracy, it made them more fashionable.[63] English watches, by contrast, were "much more solid, durable, and mathematically correct" and "fitter for service".[64]

In his 1836 report to parliament on the threat presented by Swiss manufacturers, ardent free trader John Bowring M.P. predicted that the greater durability and accuracy of English watches would protect them against competition from specimens produced for people who could not afford a costly watch. In the same vein, R. A. Church[65] cites the insouciance of "one leading London watchmaker", satisfied "that Americans would manufacture common watches for the millions, for this would leave British watchmakers to make aristocratic watches for the hundreds." Perhaps, then, the problem was not so much entrepreneurial inertia as complacency and poor judgment: that following short-term comparative advantage was a miscalculation? The trouble with that defense is that the writing had long been on the wall.

Figure 3 compares the nominal prices of labour, silver, and watches between the 1700s and the 1840s. Note that the price of watches (as measured by the median price per decade) stopped falling in the 1760s, but continued productivity growth is indicated by the continued rises in the cost of living and wages. Only in the 1820s and later do we find a rise in watch prices not matched by a corresponding or greater rise in wages. From this time on the English industry survived through reductions in workers' incomes and status.

What began as a cottage industry became one of small workshops manned by workers paid by the piece.

Figure 3 here

Nearly six decades after Rees's warning about competition from Switzerland, a Swiss expert described English watchmaking in 1878 as "completely stationary" and "almost the same now as fifty years since", as if English watchmakers believed they had already achieved "perfection"[66]. They had clung to the *fusée* long after their Swiss, German, and American rivals had switched to the going barrel, and their "calibres, escapements and ways of working" remained the same.

Inevitably the social status of watchmakers suffered. Here we use *HISCAM*, a stratified measure of occupational attainment based on nineteenth century rankings, as a proxy for economic status.[67] The data imply strong intergenerational links; both a father's and a father-in-law's *HISCAM* score affected the *HISCAM* score and literacy of the next generation. *HISCAM* is also a very good predictor of ability to sign in our database. The correlations between whether a husband and/or his wife could sign, on the one hand, and the *HISCAM* value for the husband, his father, and father-in-law, on the other (N ≈ 4,000), are given in Table 6:

Table 6 here

Regressing literacy and *HISCAM* on the previous generation's *HISCAM* using Ordinary Least Squares (OLS) for almost four thousand marriages c. 1835-1859 produces the outcome described in Table 7. This shows that a groom's status was very much linked to those of his father and father-in-law. The outcome suggests that people married their own kind. It was likewise (using LOGIT) with the ability of groom and bride to sign the marriage register. The low average *HISCAM* values for 258 watchmakers' fathers and fathers-in-law in

this period (48.92 and 44.67, respectively)— *HISCAM*'s value for watchmakers is 55.13—is consistent with a decline in the status of watchmakers. The *HISCAM* values of watchmakers' sons and sons-in-law (51.84, n=182 and 48.86, n=185, respectively), while much higher than those for unskilled workers, corroborate.

Table 7 here

Table 1 shows how in most occupational groups the share of females who could sign rose between the mid-eighteenth and mid-nineteenth centuries, but that was not so in the case of the wives of watchmakers. The literacy of watchmakers' wives lagged behind that of almost all other categories. Watchmakers themselves, too, fell behind other artisans in the watchmaking parishes. This is arguably a further reflection on the pressure under which watchmakers' incomes were towards the end of the period. Figure 4 compares the ability to sign of watchmakers and toolmakers separately, implying that the latter were of even lower status than the former.

[Figure 4 about here]

In sum, the decline of the watchmaking industry led to a decline in the status and incomes of southwest Lancashire's watchmakers and toolmakers. This is reflected in their literacy at marriage and that of their spouses; and also in the occupations of their fathers and fathers-in-law, as described in local parish registers c. 1830-1860. By mid-century the life of a Prescot apprentice was "mostly hell" and journeymen cutters were known by the unflattering sobriquet of "poverty knockers"[68]. Soon the town's remaining artisanal watchmakers would become captives of the truck system, a sure sign of their weak and declining bargaining power.[69] As an item in the *Horological Journal* lamented of the trade more generally in 1891:

> The wages paid and the prices obtained for the work of our trade, do not bear comparison with those of any other whatsoever. Here you have a really skilled man doing, in many cases, beautiful work for prices that a bicycle repairer would have a good laugh at.'[70]

V

After mid-century Swiss watches flooded into the United Kingdom. Imports per annum rose from 42,000 in 1853 to 160,000 in the early 1860s.[71] While the Swiss developed ways of combining quality and quantity, mass-produced, cheap American watches also poured in.[72] In 1854 watchmaking still employed over three hundred workers in the Prescot area, nearly half of them movement makers, and a further sixty-eight tool and file makers[73]. By 1866, when John Wycherley built a steam-powered factory in Prescot that made machine-cut standard movement sizes, most of the damage had already been done. In 1882 Wycherley, who employed a labour force of about 120, one-third of them female, sold his business to Thomas P. Hewitt, a local watch and chronometer maker, as an ongoing concern.[74] Wycherley, Hewitt and Co. would in turn be absorbed by the Lancashire Watch Company (LWC) in 1889, nearly four decades after the American Watch Company began operations in Waltham. The new company, Hewitt's brainchild, aimed at producing cheaper watches for the mass market, but it never stood a chance. It employed a workforce of over a thousand, mostly men, at its peak but it was "equipped not with very modern American plant but with old stuff from some place that wanted to get rid of its outmoded tools and machines for more modern equipment"[75]. Nor did the LWC represent a clean break from the broken artisanal tradition: to some extent the new plant housed workers employed in tool-making businesses.[76] As a former employee of the LWC reminisced much later, this was unwise:

> They (the old workmen) were very much against any alterations to these old things. Now the Swiss, when they

> introduced their cheap watch, they didn't take the old men who had been used to the good quality work, they trained up another lot which hadn't got the tradition, you see, so there was no prejudice behind them using those sort of things. Of course you can understand it, when you get a lot of very fine craftsmen who have always been used to very good work, they don't like anything cheapening anything.[77]

More important, the LWC spread itself too thinly, seeking in vain to emulate the entire range of imported styles, although production peaked at only 50,000 per year at the turn of the century. The same held for the other English watchmaking factories in operation at this time; for example, production at the Birmingham concern of William and Gustav Ehrhardt peaked at 600-700 per week around the turn of the century. The giant Waltham-based American Watch Company, by comparison, produced nine million watches between 1877 and 1901.[78] In its final years the LWC placed its hopes in tariff protection, but those hopes were shattered by the general elections of 1910.[79]

The LWC attempted to compete on price and design. The cheapest watch in a 1905 LWC trade catalogue was the "Lancashire Wizard" in a gun-metal case, costing £1 10s. The "John Bull"—described in the *Horological Journal* in June 1910 as "it is believed, the best 5s. watch that has ever been place on the market"—was its last-ditch effort[80]; but only five thousand of those were sold between November 1909 and the LWC's closure in 1910.[81] Only in one small niche did the Prescot watchmaking industry in its traditional artisanal form survive. By concentrating on the production of high quality chronometer movements, the workshop of Joseph Preston and Son, established in 1829, survived until the end of World War 2.[82]

Table 1. Movements in Apprenticeship Fees (£ nominal, quantiles)										
	Watchmakers					Other				
Period	*p10*	*p25*	*p50*	*p75*	*p90*	*p10*	*p25*	*p50*	*p75*	*p90*
<1750	10	12	20	20	26	7	14	18	20	22
1750-1779	5	10	15	20	25	4	6	10	20	24
1780-1810	6	10	15	20	30	3	5	9	13	20
Change [%]	*-40*	*-17*	-25	0	*+15*	-57	*-64*	-50	-33	-9
Source: see text										

Table 2. Presence of Grooms in Moore Database (%)		
Category	*In*	*Not in*
Groom literate, Bride literate	22.2 [40]	77.8 [140]
Groom literate, Bride illiterate	11.3 [28]	88.7 [219]
Groom illiterate	8.0 [8]	92.0 [92]
Total	14.4 [76]	85.6 [451]
Source: derived from Moore, *British Clockmakers*; Lancashire Online Parish Clerks [http://www.lan-opc.org.uk/indexp.html]. Number of observations in parentheses.		

Table 3. Absent but Presence of Same Surname in Moore Database		
Category	*In*	*Not in*
Groom literate, Bride literate	63.2 [96]	36.8 [56]
Groom literate, Bride illiterate	53.6 [120]	46.4 [104]
Groom illiterate	48.8 [41]	51.2 [43]
Total	56.3 [267]	43.7 [207]
Source: as Table 2. Number of observations in parentheses.		

Table 4. Ability to Sign by Occupational Category, 1750s-1850s						
	Males			Females		
Category	*1750-69*	*1800-19*	*1840-59*	*1750-69*	*1800-19*	*1840-59*
Professional, elite	100	100.0	100	95.7	90.0	100
White collar	100	100.0	100	60.0	72.2	80.9
Watch- and toolmakers	*94.4*	*68.3*	*71.7*	*38.9*	*24.5*	*30.2*
Farmers, yeomen	91.7	75.7	70.0	55.6	43.2	55.1
Smiths	83.3	51.4	61.4	30.6	17.1	34.7
Traders	81.5	83.1	81.5	60.2	59.7	60.2
Wood workers	79.5	82.2	83.8	37.0	27.7	51.3
Shoemakers	78.8	59.2	77.2	22.4	20.4	37.7
Construction	71.2	58.2	62.9	30.4	20.7	34.0
Clothing	66.2	53.7	89.1	27.0	20.5	47.3
Glass	65.4	50.0	60.0	34.6	30.4	33.0
Metal	60.8	44.7	60.0	27.5	10.6	30.0
Textiles	59.4	47.9	46.9	22.7	11.0	28.1
Husbandmen	48.6	42.0	52.0	13.0	18.2	4.0
Labourers	43.8	36.2	34.3	18.2	10.5	19.0
Miners	13.2	14.8	20.6	2.6	3.8	8.5
Potters	.	22.2	61.5	.	9.3	15.4
All the above	62.8	49.5	49.3	28.1	21.7	28.7
Source: Lancashire OnLine Parish Clerks [http://www.lan-opc.org.uk/indexp.html]						

Table 5. Husbands' and wives' ability to sign						
	Groom signed [%]		Bride signed [%]		N	
Period	*Watch-makers*	*Tool-makers*	*Watch-makers*	*Tool-makers*	*Watch-makers*	*Tool-makers*
1750-79	92.2	82.8	36.3	24.1	101	61
1780-1809	75.9	61.5	28.6	15.5	220	78
1810-39	69.1	57.7	27.5	23.4	204	137
1840-59	75.4	66.4	31.9	27.7	191	119
Source: as in Table 4						

Table 6. Correlations between *HISCAM* and literacy		
	Groom cannot sign	Bride cannot sign
HISCAM	-0.402	-0.353
Groom's father's *HISCAM*	-0.304	-0.255
Bride's father's *HISCAM*	-0.229	-0.282

Table 7. Intergenerational impacts: *HISCAM* and literacy			
	HISCAM	Husband can't sign	Wife can't sign
	OLS	LOGIT	LOGIT
Father's *HISCAM*	0.487 (0.014)	-0.068 (0.004)	-0.044 (0.004)
Father-in-law's *HISCAM*	0.242 (0.015)	-0.041 (0.043)	-0.058 (0.004)
Adjusted/Pseudo R^2	0.337	0.094	0.093
N	3,867	3,880	3,879

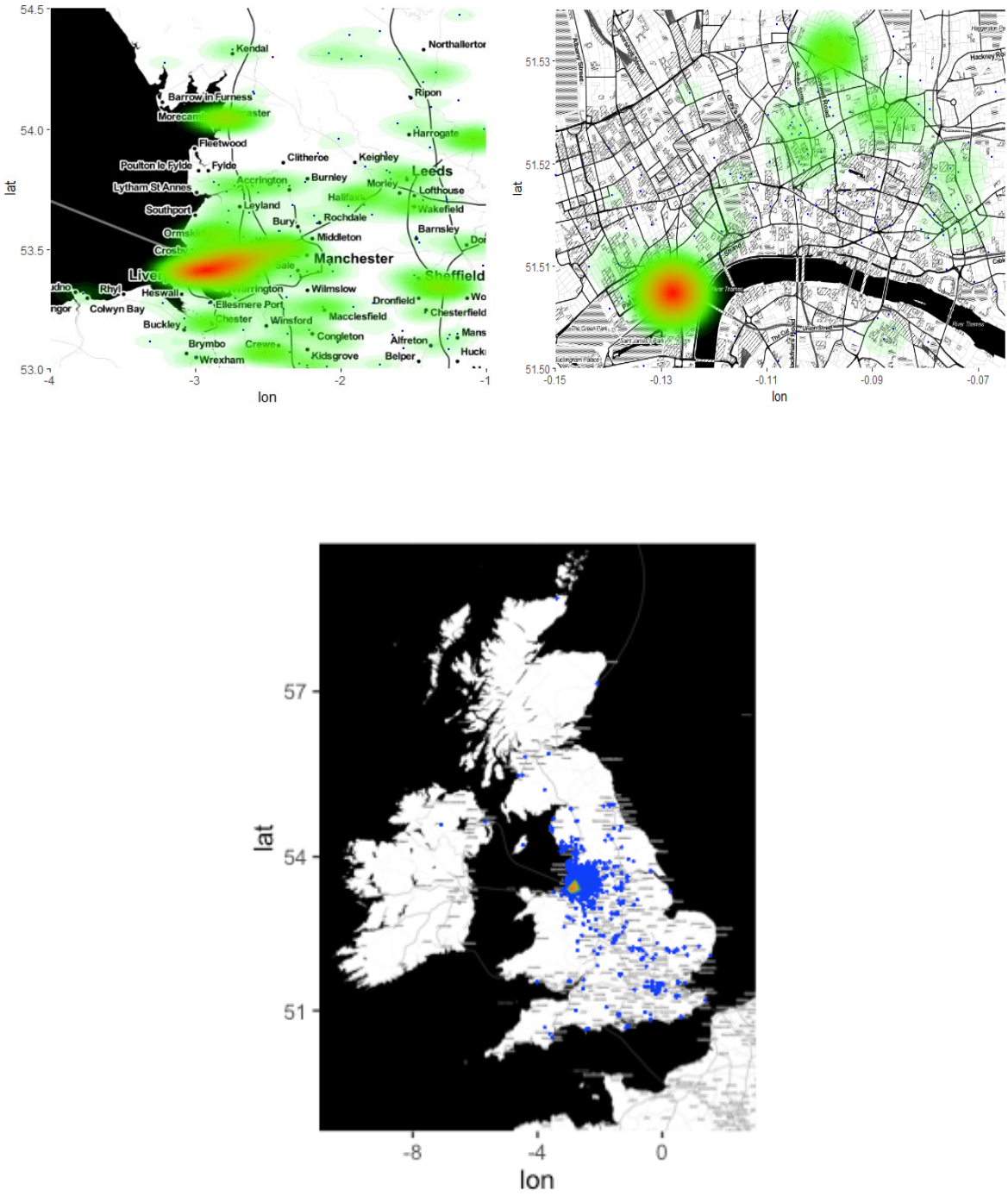

Figure 1. Apprenticeship Contracts in Lancashire, London, and Britain
Source: Moore, *British Watchmakers*

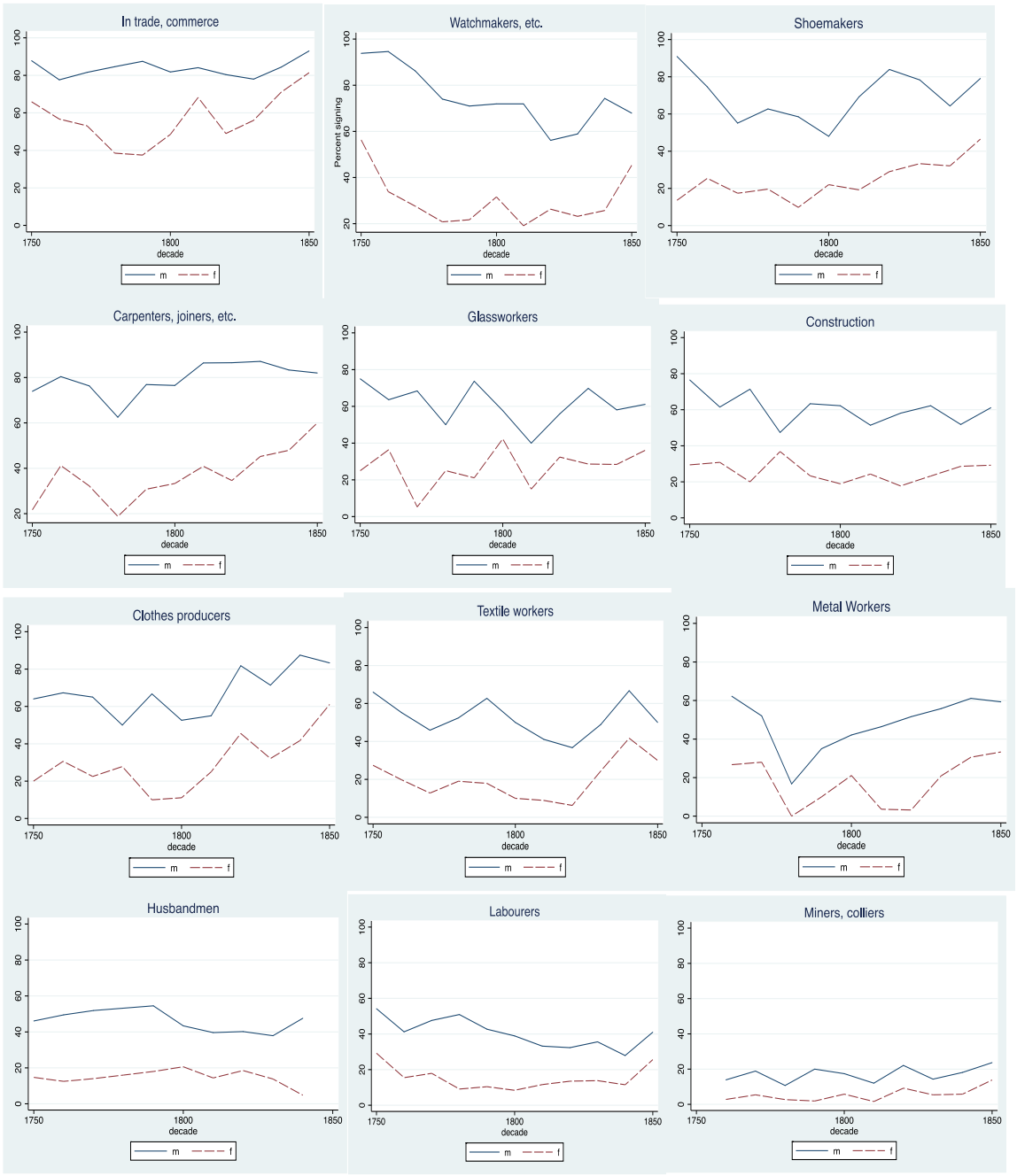

Figure 2. Ability to sign by occupation, c. 1750-1850

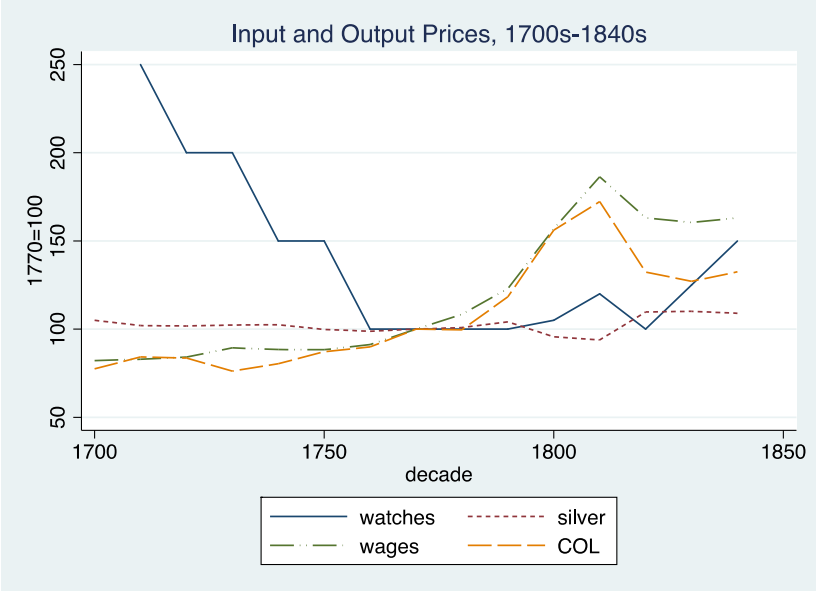

Figure 3. Wages, Watches, and Silver

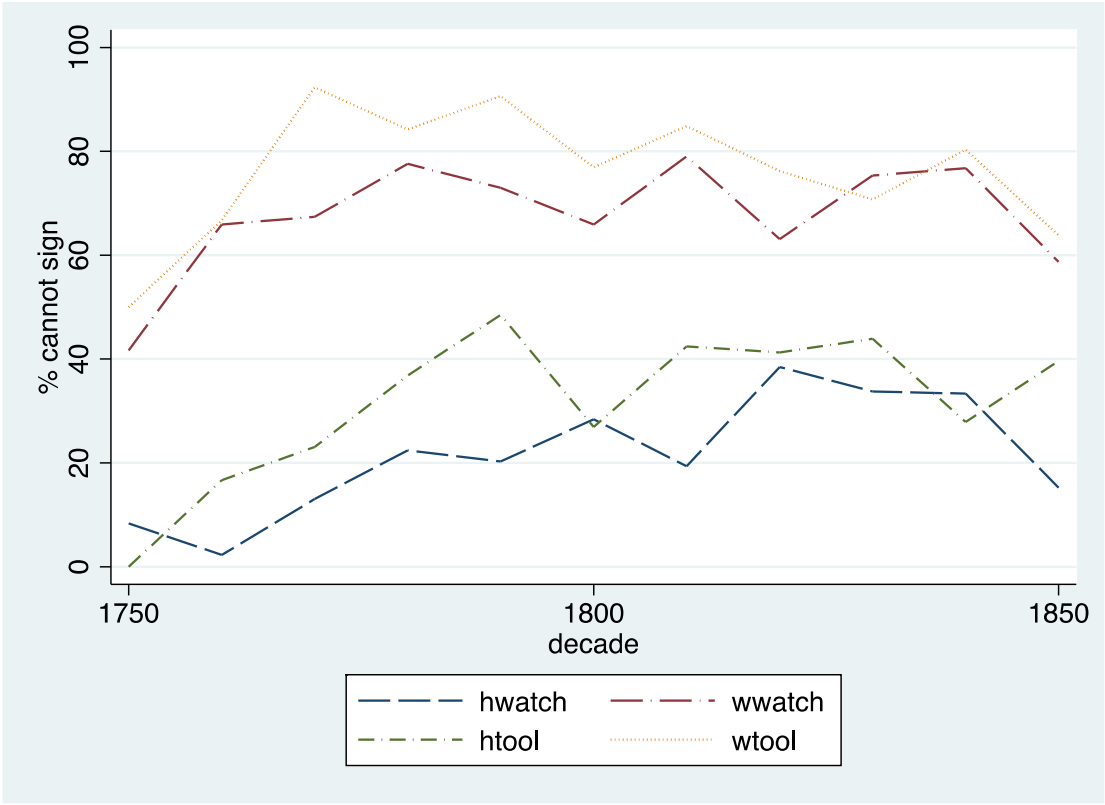

Figure 4. Literacy of Watchmakers and Toolmakers [h=husband, w=wife]

APPENDIX. Literacy and Husband's Occupation:
1750s-1760s, 1800s-1810s, and 1840s-1850s

Appendix Table 1a. Percentage who could sign in the 1750s and 1760s			
Category	Husbands	Wives	N
Professional, elite	100	95.7	23
White collar	100	60.0	10
Watch- and toolmakers	94.4	38.9	72
Farmers, yeomen	91.7	55.6	36
Smiths	83.3	30.6	36
Traders	81.5	60.2	108
Shoemakers	78.8	22.4	85
Wood workers	79.5	37.3	83
Construction	71.2	30.4	52
Clothing	66.2	27.0	74
Glass	65.4	34.6	26
Metal	60.8	27.5	51
Textiles	59.4	22.7	278
Husbandmen	48.6	13.0	407
Labourers	43.8	18.2	121
Miners	13.2	2.6	39
Potters	.	.	.

Appendix Table 1b. Percentage who could sign in the 1800s and 1810s			
Category	Husbands	Wives	N
Professional, elite	100	90.0	30
White collar	100	72.2	18
Watch- and toolmakers	68.3	24.5	220
Farmers, yeomen	75.7	43.2	169
Smiths	51.4	17.1	70
Traders	83.1	59.7	77
Shoemakers	59.2	20.4	103
Wood workers	82.2	27.7	101
Construction	58.2	20.7	79
Clothing	53.7	20.5	39
Glass	50.0	30.4	46
Metal	44.7	10.6	47
Textiles	47.9	11.0	163
Husbandmen	42.0	18.2	286
Labourers	36.2	10.5	354
Miners	14.8	3.8	391
Potters	22.2	9.3	54

Appendix Table 1c. Percentage who could sign in the 1840s and 1850s			
Category	Husbands	Wives	N
Professional, elite	100	100	48
White collar	100	80.9	69
Watch- and toolmakers	71.7	30.2	291
Farmers, yeomen	70.0	55.1	147
Smiths	61.4	34.7	101
Traders	81.5	60.2	108
Shoemakers	77.2	37.7	114
Wood workers	83.8	51.3	117
Construction	62.9	34.0	159
Clothing	89.1	47.3	55
Glass	60.0	33.0	185
Metal	60.0	30.0	70
Textiles	46.9	28.1	32
Husbandmen	52.0	4.0	25
Labourers	34.3	19.0	1,228
Miners	20.6	8.5	694
Potters	61.5	15.4	26

ENDNOTES:

[1] The helpful comments and advice of Alun C. Davies, Kevin Denny, Alan Fernihough, Morgan Kelly, Joel Mokyr, John Platt, Peter Solar, Darlah Thomas, and Patrick Wallis on an earlier draft are much appreciated. The paper is dedicated to the memory of the late Dennis Moore, horologist *extraordinaire*.

[2] E.g. John L. Hammond and Barbara Hammond, *The Skilled Labourer*. London: Longman, 1919; E. P. Thompson, *The Making of the English Working Class*. London: Gollancz, 1963; A. E. Musson and E. Robinson, *Science and Technology in the Industrial Revolution*. Manchester: Manchester University Press, 1969; compare Alexandra de Pleijt and Jacob Weissdorf, 'Human capital formation from occupations: the 'deskilling hypothesis' revisited', *Cliometrica* 11(1) (2017), 1-30.

[3] Margaret Jacob, *The First Knowledge Economy: Human Capital and the European Economy, 1750-1850*, Cambridge: Cambridge University Press, 2014; Ó Gráda, 'Did science cause the Industrial Revolution?' *Journal of Economic Literature*, 54[1] (2016), 224-39.

[4] Gillian Cookson, 'The West Yorkshire Textile Engineering Industry, 1780-1830' unpublished D.Phil. dissertation, University of York, 1994; id. *The Age of Machinery: Engineering the Industrial Revolution, 1770-1850*. Boydell & Brewer: Martlesham, Suffolk, 2018.

[5] Compare Sheelagh Ogilvie, 'The economics of guilds'. *Journal of Economic Perspectives* 28[4] (2014), 169-92; David de la Croix, Matthias Doepke, and Joel Mokyr, 'Clans, Guilds, and Markets: Apprenticeship Institutions and Growth in the Pre-Industrial Economy', *Quarterly Journal of Economics*, 122[1] (2018), 1-70; Jane Humphries, Humphries, Jane. 2006. 'English apprenticeship: a neglected factor in the first industrial revolution'. In David and Mark Thomas, eds. *The Economic Future in Historical Perspective*. Oxford: Oxford University Press, pp. 73-102.

[6] Morgan Kelly and Cormac Ó Gráda, 'Adam Smith, Watch Prices, and the Industrial Revolution', *Quarterly Journal of Economics*, 131[4] (2016), 1727–1752. Assuming that Britain produced 200,000 watches worth an average of £1 c. 1800 and that British national income c. 1800 was £200-250 million would imply that watches then contributed no more than 0.1 per cent to national income. Thus, while its technological spill-overs were important, the macroeconomic impact of productivity change in the sector was small.

[7] Alan Smith, 'An early 18th century watchmaker's notebook: Richard Wright of Cronton and the Lancashire-London connection', *Antiquarian Horology*, 15[6] (1985), 610-15. This is not to imply that Lancashire produced no watch finishers: see J. G. Platt, 'Prescot Watches' [http://lancashirewatchcompany.co.uk/lancashire-watch-company-prescot/prescot-watches/].

[8] Weiss, *Watch-making*, 49-50; Smith, 'An early 18th century watchmaker's notebook'; Philipp Andreas Nemnich, *Neueste Reise durch England, Schottland und Irland*... Tübingen: Cotta, 1807, 137. Later, after the English watchmaking sector had long passed its peak, Warwickshire would overtake southwest Lancashire (Darlah Thomas, 'A snapshot of the watchmaking industry in England through the lens of the 1881 census', *Antiquarian Horology*, 40[1] (2019), 36-58).

[9] E.g. G. H. Tupling, 'The Early Metal Trades and the Beginnings of Engineering in Lancashire', *Transactions of the Lancashire and Cheshire Antiquarian Society*, LXI (1949),11-25; F. A. Bailey and T. C. Barker, 'The Seventeenth-century Origins of Watch-making in South-west Lancashire', in J. R. Harris, ed. *Liverpool and Merseyside*. London: Cass, 1959, 1-15; David S. Landes, 'Watchmaking: A Case Study in Enterprise and Change', *Business History Review*, 53[1] (1979), 1-39; id. *Revolution in Time: Clocks and the Making of the Modern World.* Cambridge, Mass.: Harvard University Press, 1983; Leonard Weiss, *Watch-making in England 1760-1820*. London; Robert Hale, 1982, 51-72; A.A. Treherne, 'The contribution of south-west Lancashire to horology, Part 1. Watch and chronometer movement making and finishing', *Antiquarian Horology*, 31 (2009), 457-76; Alun C. Davies, 'Time for a Change? Technological Persistence in the British Watchmaking Industry', *Material History Review* 36 (1992) 57-64; Michael J. Enright, 'Organization and Coordination in Geographically Concentrated Industries', in Naomi Lamoreaux and Dan Raff, eds. *Coordination and Information: Historical Perspectives on the Organization of Enterprise*. Chicago: University of Chicago Press, 1995, 103-46; Amy Glasmeier, *Manufacturing Time: Global Competition in the Watch Industry, 1795-2000* New York: Guilford Press, 2000. In the words of Weiss, *Watch-making*, 57, 'Prescot ... is almost built over coal mines'.

[10] 'Townships: Prescot', in *A History of the County of Lancaster: Volume 3*, ed. William Farrer and J Brownbill (London, 1907), pp. 353-354 [*British History Online* http://www.british-history.ac.uk/vch/lancs/vol3/pp353-354; accessed 5 July 2018]; Weiss, *Watch-making*, 54-55.

[11] Bailey and Barker 1969; Weiss, *Watch-making*, 54; R. J. Griffiths, 'The Early Watchmakers of Toxteth Park Near Liverpool and the origins of the industry: the Aspinwalls with notes on their successors', Antiquarian Horology 27[2] (2002), 163-78.

[12] James Hoult, 'Prescot Watch-making in the xviii Century', *Transactions of the Historic Society of Lancashire and Cheshire*, LXXVII (1926), 39-53 (at 42).

[13] Liverpool Museums horology database, compiled by Dennis Moore. See http://www.liverpoolmuseums.org.uk/wml/collections/horology/database.asp. See too Hoult, 'Prescot Watch-making'.

[14] J. Aikin, *A Description of the Country from Thirty to Forty Miles Around Manchester*, London: John Stockdale, 1795, 309-11; Matthew Gregson, *Portfolio of Fragments Relative to the History and Antiquities of the Country and Palatine of Lancaster*... Liverpool: Harris, 1817 [p. 181 of 3rd ed. 1863 re Prescot/Widnes];

Anon. 'Historical overview of Prescot and the watchmaking industry', re-published in J.G. Platt, *Lancashire Watch Company: History and Watches* Chester: Inbeat Publications, 2016, 12; Thomas Pennant, *A Tour from Downing to Alston Moor*, London: Oriental Press. 1801, 21.

[15] Weiss, *Watch-making*, 56-58. For a detailed account of the division of labour between Prescot and London craftsmen, see Abraham Rees, 'Watch-maker', *The Cyclopaedia or Universal Dictionary of Arts, Sciences, and Literature*, vol. 37, no page given, 1819.

[16] Smith, 'An early Eighteenth-century Watchmaker's Notebook', 618; Aikin, *A Description*, 312.

[17] E.g. Robert Campbell, *London Tradesman.* London: Gardner, 1747; Rees, *Cyclopaedia*, vol. 37, no page given, 1819.

[18] Kelly and Ó Gráda, 'Adam Smith'.

[19] Weiss, *Watch-making*, 34.

[20] Weiss, *Watch-making*, 43; Ian Anders Gad and Patrick Wallis, 'Reaching beyond the city wall: London guilds and national regulation, 1500-1700', in S. R. Epstein and Maarten Prak, eds. *Guilds, Innovation and the European Economy, 1400-1800*, Cambridge, Cambridge University Press, 2009, 288-316.

[21] Chris Minns and Patrick Wallis, 'Rules and Reality: Quantifying the Practice of Apprenticeship in Early Modern England', *Economic History Review*, 65[2] (2012), 556-579.

[22] Herbert Heaton, *The Yorkshire woollen and worsted industries, from the earliest times up to the Industrial revolution*, Oxford: Clarendon Press, 1920, 306-11; Cookson, *The Age of Machinery*, 152.

[23] Compare Chris Minns and Patrick Wallis, 'The price of human capital in a pre-industrial economy: premiums and apprenticeship contracts in 18th century England', *Explorations in Economic History* 50[3] (2013), 335-50.

[24] Hoult, 'Prescot Watch-making', 43; Dennis Moore, 'Halewood Parish Apprenticeship Indentures'. *National Association of Watch & Clock Collectors Bulletin*, 2008, 207.

[25] For Prescot alone, the Liverpool Museums horology database includes the following occupations: broach maker, ambidextrous toolmaker, chronometer maker, file cutter, engraver, fuse manufacturer, movement maker, wire drawer, nipper maker, plier-pincer-nipper, screw maker, toolmaker, balance maker, barrel maker, bolt-and-spring maker, watch cock maker, detent maker, escapement maker, finishers, frame maker, hand maker, movement maker, pinion maker, spring maker, watch wheel cutter.

[26] Patrick Wallis, 'Apprenticeship in England', in Maarten Prak and Patrick Wallis, eds. *Apprenticeship in Early Modern Europe*, Cambridge, Cambridge University Press, 2020, pp. 247-81; J. Lane, *Apprenticeship in England, 1600-1914*,

London, UCL Press, 1996, p. 159; Caroline Louise Withall, 'Shipped out? Pauper Apprentices of Port Towns during the Industrial Revolution 1750-1870', Unpublished PhD dissertation, University of Oxford, 2014 [available at: https://ora.ox.ac.uk/objects/uuid:519153d8-336b-4dac-bf37-4d6388002214/download_file?file_format=pdf&safe_filename=Thesis%2BORA%2Bcopy.pdf&type_of_work=Thesis], pp. 86-88, 241-42.

[27] Widnes, Rainford, Sankey, Halewood, St. Helens, Warrington.

[28] Compare de la Croix, Doepke, and Mokyr, 'Clans, guilds, and markets'.

[29] In mid-eighteenth century London it cost £10-£20 to apprentice a shoemaker, £10-£30 a tailor, and £10-£50 a watchmaker (Giorgio Riello, 'The Boot and Shoe Trades in London and Paris in the Long Eighteenth Century', Unpublished PhD Thesis, University College London, 2002, 74, citing J. Collyer, *The Parent's and Guardian's Directory* (London, 1761), pp. 249, 288-910). But the status of watchmakers in eighteenth-century London is likely to have been higher than in Lancashire (compare Lane 2005: 138-142).

[30] Aikin, *A Description*, 311; John Britton, *The Beauties of England and Wales*. Vol. 9. London: Vermor *et al*., 1807, 226; Anon. 'Historical overview of Prescot and the watchmaking industry', re-published in J.G. Platt, *Lancashire Watch Company*, Chester: Inbeam, 2016, 12.

[31] Joseph Wickham Roe, *English and American Tool Builders: Henry Maudslay English and American Tool Builders* New York: McGraw-Hill, 1916, 65; Weiss, *Watch-making*, 170-71.

[32] Ashton, *An Eighteenth-century Industrialist*, 38; David Hey, 'The South Yorkshire Steel Industry and the Industrial Revolution', *Northern History* 42[1] (2005), 91-96.

[33] Register of the Church of St. Ephin, Warrington (http://www.lan-opc.org.uk/Warrington/stelphin/index.html).

[34] Thomas H. Ashton, *An Eighteenth-century Industrialist: Peter Stubs of Warrington, 1756-1806*. Manchester: Manchester University Press, 1939.

[35] R.A.H. Ward, 'A Watchmaker's Pocket Book', *Transactions of the Historic Society of Lancashire and Cheshire,* 122 (1970), 153-7.

[36] For a useful account of this measure of literacy see Rab Houston, *Literacy in Early Modern Europe: Culture and Education, 1500-1800*, 2nd ed. London: Longman, *2002: 132-3*.

[37] Joan Thirsk, 'Agricultural Innovations and their Diffusion' in J. Thirsk, ed. *The Agrarian History of England and Wales*, vol. 5[II], Cambridge: Cambridge University Press, 1985, 571-4.

[38] Jaime Reis, 'Economic growth, human capital formation and consumption in western Europe before 1800' in R.C. Allen, T. Bengtsson, and Martin Dribe, eds. *Living Standards in the Past*. Oxford: Oxford University Press, 2005, 195-225.

[39] Although this, as Joel Mokyr reminds us, takes no account of how literate mothers might have taught their sons how to read.

[40] Cited in Barker and Harris, *A Merseyside Town*, 128. Compare R. C. Allen, *The British Revolution in Global Perspective*. Oxford: OUP, 2009, 204-6.

[41] *Science and Technology*, 435-39.

[42] "During the lengthy litigation between the Cornish engineers and Boulton & Watt, Trevithick's brother-in-law and friend, William West (1751-1831), a blacksmith and noted clockmaker, made model engines as court exhibits. Trevithick was thinking about engines that did not require a beam or a condenser, ones that could move instead of being built into an engine house. West made at least one model for him in which the engine and boiler were combined, and 'the little machine was said to run around the Trevithicks' kitchen" (Engineering Biography: Richard Trevithick: http://www.engineering-timelines.com/who/Trevithick_R/trevithickRichard3.asp).

[43] Ben Russell, *James Watt: Making the World Anew*. London: Reaktion Books, 2014; Cookson, *The Age of Machinery*, 79-80.

[44] For instance, Thomas Porthouse who co-invented a flax-spinning machine in 1787 was a clockmaker in Darlington; but the process he devised relied on skills quite removed from machinery and metal instruments (Anon. *The Repertory of Arts and Manufactures.* Vol. 1, 73).

[45] Cookson 'The West Yorkshire Textile Engineering Industry', 54. However, horologist Darlah Thomas has pointed out to us that Richard Roberts, 'made several turret clocks and cut wheels for other clockmakers. His clocks are very distinctive, though few survive'.

[46] Dane, *Peter Stubs*, 67.

[47] Hoult, 'Prescot Watch-making', 45.

[48] Roberts and Pidgeon, 'Sketch of Mr. John Wyke, with remarks on the arts and manufactures in Liverpool, from 1760 to 1780', *Proceedings of the Historic Society of Lancashire and Cheshire*, VI (1853-54), 69, 71; Alan Smith, *A Catalogue of Tools for Watch and Clock Makers by John Wyke of Liverpool.* Charlottesville: University Press of Virginia 1978. Compare Ford, Whitmore and Brunton, *All Sorts of Files, Tools & Engines, for Clock & Watch Makers, Gold & Silversmiths & Jewellers Tools, Engine, Oval & Common Lathes Rollers or Flatting Mills …*, 1780. Birmingham.

[49] Eliza Meteyard, *The Life of Josiah Wedgwood from his Private Correspondence and Family Papers.* Vol. 2. London: Hurst & Bennett, 1866, 17-18.

[50] Science Museum, London: 'Dial micrometer, 1760-1772' [https://collection.sciencemuseum.org.uk/objects/co1681/dial-micrometer-1760-1772-dilatometer].

[51] A. D. Morrison-Low, *Making Scientific Instruments in the Industrial Revolution*. London: Routledge, 2007; John Hawkins, 'Staffordshire Engine

Turned Pottery 1760-1780'. *Bulletin of the Society of Ornamental Turners* 20[100] (1999), 213-20.

[52] Maxine Berg, 'New commodities, luxuries, and their consumers in eighteenth-century England, in Maxine Berg and Helen Clifford, eds. *Consumers and Luxury: Consumer Culture in Europe 1650-1850* Manchester: Manchester University Press, 1999, 75.

[53] H. W. Dickinson, *Matthew Boulton*. Cambridge: Cambridge University Press, 1937, 96; Jennifer Tann, 'Borrowing brilliance: technology transfer across sectors in the early Industrial Revolution', *International Journal for the History of Engineering and Technology* 85[1] (2015), 94-114.

[54] Theodere Z. Penn, 'Review of Dane, *Peter Stubs*', *Technology and Culture*, 16[2] (1975), 299-301, at 300.

[55] *A Description*, 311.

[56] Ashton, *An Eighteenth Century Industrialist*, 146-7; Musson and Robinson, *Science and Technology*, 439; E. Surrey Dane, *Peter Stubs and the Lancashire Hand Tool Industry*. Altrincham: Sherratt, 1973, 66.

[57] Dane, *Peter Stubs*, 66; compare Cookson, 'The West Yorkshire Textile Engineering Industry'.

[58] James Nasmyth, *Autobiography*, 1885, ch. 12 [available at: http://www.anvilfire.com/21centbs/stories/James_Nasmyth/jn12.htm]. The William Stubbs (1789-1854) mentioned was one of the Peter's sons. Ashton (*An Eighteenth-century Industrialist*, 3) cites part of this excerpt. For more in the same vein see e.g. John Holland, *A Treatise on the Progressive Improvement & Present State of the Manufactures in Metal,* Vol. 2. London, 1831, 318; Musson and Robinson, *Science and technology*, 437; A.E. Musson, 'The Engineering Industry', in R. A. Church, ed. *The Dynamics of Victorian Business*. London: Allen & Unwin, 90.

[59] Compare Chris Evans, 'Steel in Britain before and after Benjamin Huntsman: manufacture and consumption in the eighteenth century' in Philippe Dillmann, Liliane Perez, and Catherine Verna, eds. *L'acier en Europe avant Bessemer*. Toulouse: CNRS, 2011, pp. 285-98 [https://www.academia.edu/210732/Steel_in_Britain_before_and_after_Benjamin_Huntsman_manufacture_and_consumption_in_the_eighteenth_century]; Chris Evans and Alun Withey. 'An enlightenment in steel? Innovation in the steel trades in eighteenth-century Britain', *Technology & Culture* 53[2] (2012), 533-560.

[60] Allen, *The British Industrial Revolution*; Roman Studer, 'When did the Swiss get so rich? Comparing living standards in Switzerland and Europe, 1800-1913'. *Journal of European Economic History*, 37 (2008), 405-51 (Table 2). Compare Landes, 'Watchmaking', 16.

[61] *Manchester Times*, 'The *London "Standard"* and the Manufacture of Watches', November 5 1842.

[62] Roman Studer, 'When did the Swiss get so rich? Comparing living standards in Switzerland and Europe, 1800-1913'. *Journal of European Economic History*, 37 (2008), Table 2. Compare Landes, 'Watchmaking', 16.

[63] Davies, 'Time for a change?', 58-9.

[64] Anon. 'The manufacture of watches in Switzerland', *The Saturday Magazine* 22 October 1842, 158; John Bowring, *Report on the Commerce and Manufactures of Switzerland*, London: His Majesty's Stationery Office, 1836.

[65] Church, 'Nineteenth-century clock technology in Britain, the United States, and Switzerland' *Economic History Review*, New Series, 28[4] (1975), 625.

[66] Davies, 'Time for a change?'; *Leeds Mercury,* 'English and Swiss Watches', 28 November 1878.

[67] Paul S. Lambert, Paul S., Richard L. Zijdeman, Marco H. D. Van Leeuwen, Ineke Maas, and Kenneth Prandy. 2013. 'The Construction of HISCAM: A Stratification Scale Based on Social Interactions for Historical Comparative Research', *Historical Methods*, 46[2] (2013), 77-89.

[68] Hoult, Prescot watch-making', 52-53.

[69] T.C. Barker, T.C. and J. R. Harris, *A Merseyside Town in the Industrial Revolution: St Helens 1750-1900*. Liverpool: University of Liverpool Press, 1954, 370-71; *Liverpool Mercury*, 'The truck commissioners at Prescot', 2 January.

[70] *Horological Journal* 34 (1891), 23 (as cited in Alun C. Davies, 'British watchmaking and the American system', *Business History*, 35[1] (1993), 45).

[71] Barker and Harris, *A Merseyside Town*, 370.

[72] *Scientific American*, "Watchmaking,", 13[14]: 108.

[73] Hoult, 'Prescot Watch-making', 50.

[74] J. G. Platt, *Lancashire Watch Company*, 47-70

[75] Frank Mercer, 'The Decline of Watchmaking in Great Britain', *Horological Journal*, 107[III] (1965) (as cited in http://lancashirewatchcompany.co.uk/mercer-letter-to-horological-journal-1965/).

[76] Davies, 'Time for a change?', 62; Landes, *Revolution in Time*, 302.

[77] Cited in Smith, *Catalogue*, 17; see too Edward Rigg, 'Watchmaking', *Journal of the Society of the Arts*, XXIX[1497] (1881), 701-08.

[78] Landes, 'Watchmaking', 28.

[79] Platt, *Lancashire Watch Company*, 178.

[80] Some specimens are shown in Platt, *Lancashire Watch Company*, 344-46.

[81] Alan Smith and Henry G. Abbott, *The Lancashire Watch Company: Prescot, Lancashire, England 1889-1910.* Fitzwilliam, New Hampshire: Ken Roberts Publishing, 1973: 37.

[82] Alun C. Davies, 'The Life and Death of a Scientific Instrument: The Marine Chronometer, 1770-1920', *Annals of Science* 35 (1978), 509-525; id. 'The Rise and Decline of Chronometer Manufacturing', *Antiquarian Horology*, 12[3] (1980), 285–99; Treherne, 'Contribution'; 473, 476.